Annex H

Methodology for Estimating Methane Emissions from Manure Management

Step 1: Collect Livestock Population Data

All livestock population data, except for horses, were taken from U.S. Department of Agriculture (USDA) statistical reports. For each animal category, the USDA publishes monthly, annual, and multi-year livestock population and production estimates. Multi-year reports include revisions to earlier published data. Recent reports were obtained from the USDA Economics and Statistics System website, at <http://www.mannlib.cornell.edu/usda/>, while historical data were downloaded from the USDA National Agricultural Statistics Service (NASS) website at <http://www.usda.gov/nass/pubs/dataprd1.htm>.

Dairy cow and swine population data by farm size for each state, used in Step 2, were found in the *1992 Census of Agriculture* published by the U.S. Department of Commerce (DOC). This census is conducted every five years. Data from the census were obtained from the USDA NASS website at <http://www.nass.usda.gov/census/>.

The Food and Agriculture Organization (FAO) publishes horse population data. These data weree accessed from the FAOSTAT database at <http://apps.fao.org/>. Table H-1 summarizes the published population data by animal type.

Step 2: Estimate State Methane Conversion Factors for Dairy Cows and Swine

Data from EPA (1993) were used for assessing dairy and swine manure management practices by farm size. Based on this assessment, an average methane conversion factor (MCF) was assigned to each farm size category for dairy and swine farms, indicating the portion of the methane producing potential realized. Because larger farms tend to use liquid manure management systems, which produce more methane, the MCFs applied to them were higher for smaller farm sizes.

Using the dairy cow and swine populations by farm size in the DOC *Census of Agriculture* for each state, weighted average dairy and swine MCFs were calculated for each state. The MCF value for each state reflected the distribution of animals among farm sizes within the state. Table H-2 provides estimated MCF values.

Step 3: Estimate Methane Emissions from Swine

For each state, the total swine population was multiplied by volatile solids (VS) production rates to determine total VS production. Estimated state level emissions were calculated as the product of total VS production multiplied by the maximum methane production potential for swine manure (B_o), and the state MCF. Total U.S. emissions are the sum of the state level emissions. The VS production rate and maximum methane production potential are shown in Table H-3.

Step 4: Estimate Methane Emissions from Dairy Cattle

Methane emissions from dairy cow manure were estimated using the same method as emissions from swine (Step 3), but with an added analysis to estimate changes in manure production associated with changes in feed intake, or dry matter intake (DMi). It is assumed that manure and VS production will change linearly with changes in dry matter intake (DMi).

Changes in DMi were calculated reflecting changes in feed intake associated with changes in milk production per cow per year. To estimate the changes in feed intake, a simplified emission factor model was used for dairy cow enteric fermentation emissions (see Annex G). This model estimates the change in DMi over time relative to 1990, which was used to calculate VS production by dairy cows by state, as summarized in the following equation: (Dairy cow population) x (VS produced per cow) x (DMi scaling factor). Methane emissions were then calculated as follows:

(VS produced) x (Maximum methane production potential for dairy cow manure) x (State-specific MCF). Total emissions were finally calculated as the sum of the state level emissions. The 1990 VS production rate and maximum methane production potential are shown in Table H-3.

Step 5: Estimate Methane Emissions for Other Animals

The 1990 methane emissions for the other animal types were estimated using the detailed method described above for dairy cows and swine (EPA 1993). This process was not repeated for subsequent years for these other animal types. Instead, national populations of each of the animal types were used to scale the 1990 emissions estimates to the period 1991 through 1996.

Emission estimates are summarized in Table H-4.

Table H-1: Livestock Population (1000 head)

	1990	1991		1993	1994		1996
Dairy Cattle		**13,980**	**13,830**		**13,686**	**13,514**	
Dairy Cows	10,007		9,714	9,679		9,493	9,408
	4,135	4,097		4,088	4,072		3,902
Swine		**56,478**	**58,532**		**60,018**	**59,792**	
Beef Cattle	**86,065**		**88,546**	**90,317**		**94,364**	**93,683**
	7,252	7,927		7,838	8,063		7,822
Feedlot Heifers		4,144	3,884		4,088	3,934	
Feedlot Cow/Other	88		92	95		97	96
	2,180	2,198		2,239	2,304		2,346
NOF Calves		23,854	24,118		24,692	25,184	
NOF Heifers	8,740		9,261	9,727		10,790	10,800
	7,554	7,356		8,081	8,108		8,594
NOF Cows		32,860	33,359		35,227	35,531	
Sheep	**11,356**		**10,797**	**10,201**		**8,886**	**8,454**
	7,961	7,799		7,140	6,775		5,875
Rams/Weth>1yr		361	350		314	282	
Ewes<1yr	1,491		1,432	1,349		1,167	1,107
	381	373		348	332		282
Sheep on Feed		1,177	1,093		1,044	957	
Goats	**2,545**		**2,645**	**2,605**		**2,495**	**2,495**
	1,703,037	1,767,513		1,895,851	1,971,404		2,091,364
Hens>1yr		117,178	121,103		134,876	133,767	
Pullets laying	153,916		163,397	158,938		164,526	165,304
	34,222	34,272		33,833	32,808		31,316
Pullets<3mo		42,344	45,160		44,875	45,494	
Chickens	6,546		7,113	7,240		7,641	7,243
	1,172,830	1,227,430		1,338,862	1,403,508		1,519,640
Other (Lost)		7,278	7,025		12,744	8,152	
Other (Sold)	41,672		41,538	39,606		40,917	39,588
	128,384	129,505		130,750	131,375		137,595
Horses		**5,650**	**5,850**		**6,000**	**6,000**	

Table H-2: Dairy Cow and Swine Methane Conversion Factors

State	Dairy Cow	Swine	State	Dairy Cow	Swine
AK	0.35	0.35	MT	0.16	0.39
AL	0.23	0.28	NC	0.20	0.65
AR	0.45	0.59	ND	0.05	0.22
AZ	0.09	0.68	NE	0.08	0.34
CA	0.44	0.44	NH	0.12	0.36
CO	0.31	0.46	NJ	0.13	0.26
CT	0.19	0.01	NM	0.42	0.47
DE	0.21	0.29	NV	0.36	0.50
FL	0.41	0.23	NY	0.11	0.22
GA	0.27	0.35	OH	0.07	0.30
HI	0.40	0.40	OK	0.13	0.31
IA	0.04	0.38	OR	0.25	0.35
ID	0.23	0.27	PA	0.06	0.35
IL	0.07	0.42	RI	0.07	0.59
IN	0.06	0.43	SC	0.29	0.40
KS	0.09	0.33	SD	0.06	0.26
KY	0.06	0.30	TN	0.14	0.28
LA	0.19	0.30	TX	0.31	0.30
MA	0.13	0.40	UT	0.21	0.34
MD	0.15	0.42	VA	0.17	0.34
ME	0.10	0.01	VT	0.11	0.09
MI	0.12	0.42	WA	0.29	0.29
MN	0.04	0.38	WI	0.05	0.27
MO	0.07	0.33	WV	0.11	0.11
MS	0.17	0.35	WY	0.12	0.20

Table H-3: Dairy Cow and Swine Constants

Description	Dairy Cow	Swine	Source
Typical Animal Mass (kg)	640	150	ASAE 1995
kg VS/day per 1000 kg mass	10	8.5	ASAE 1995
Maximum methane generation potential (B_o) m^3 methane/kg VS	0.24	0.47	EPA 1992

Animal Type	1990	1992	1993	1995
Dairy Cattle	**0.75**		**0.77**	**0.79**
Dairy Cows	0.59		0.61	0.63
Dairy Heifers	0.16		0.16	0.16
Swine	**1.44**		**1.51**	**1.60**
Beef Cattle	**0.20**		**0.21**	**0.22**
Feedlot Steers	0.03		0.03	0.03
Feedlot Heifers	0.02		0.02	0.02
Feedlot Cow/Other	0.00		0.00	0.00
NOF Bulls	0.01		0.01	0.01
NOF Calves	0.02		0.02	0.02
NOF Heifers	0.02		0.02	0.02
NOF Steers	0.01		0.02	0.02
NOF Cows	0.10		0.10	0.11
Sheep	**0.004**		**0.003**	**0.003**
Ewes > 1 yr	0.003		0.003	0.002
Rams/Weth > 1 yr	0.000		0.000	0.000
Ewes < 1 yr	0.000		0.000	0.000
Rams/Weth < 1 yr	0.000		0.000	0.000
Sheep on Feed	0.000		0.000	0.000
Goats	**0.001**		**0.001**	**0.001**
Poultry	**0.27**		**0.28**	**0.30**
Hens > 1 yr	0.05		0.06	0.06
Pullets laying	0.06		0.06	0.06
Pullets > 3 mo	0.01		0.01	0.01
Pullets < 3 mo	0.01		0.01	0.01
Chickens	0.00		0.00	0.00
Broilers	0.10		0.11	0.12
Other (Lost)	0.00		0.00	0.00
Other (Sold)	0.01		0.01	0.01
Turkeys	0.03		0.03	0.03
Horses	**0.03**		**0.03**	**0.03**